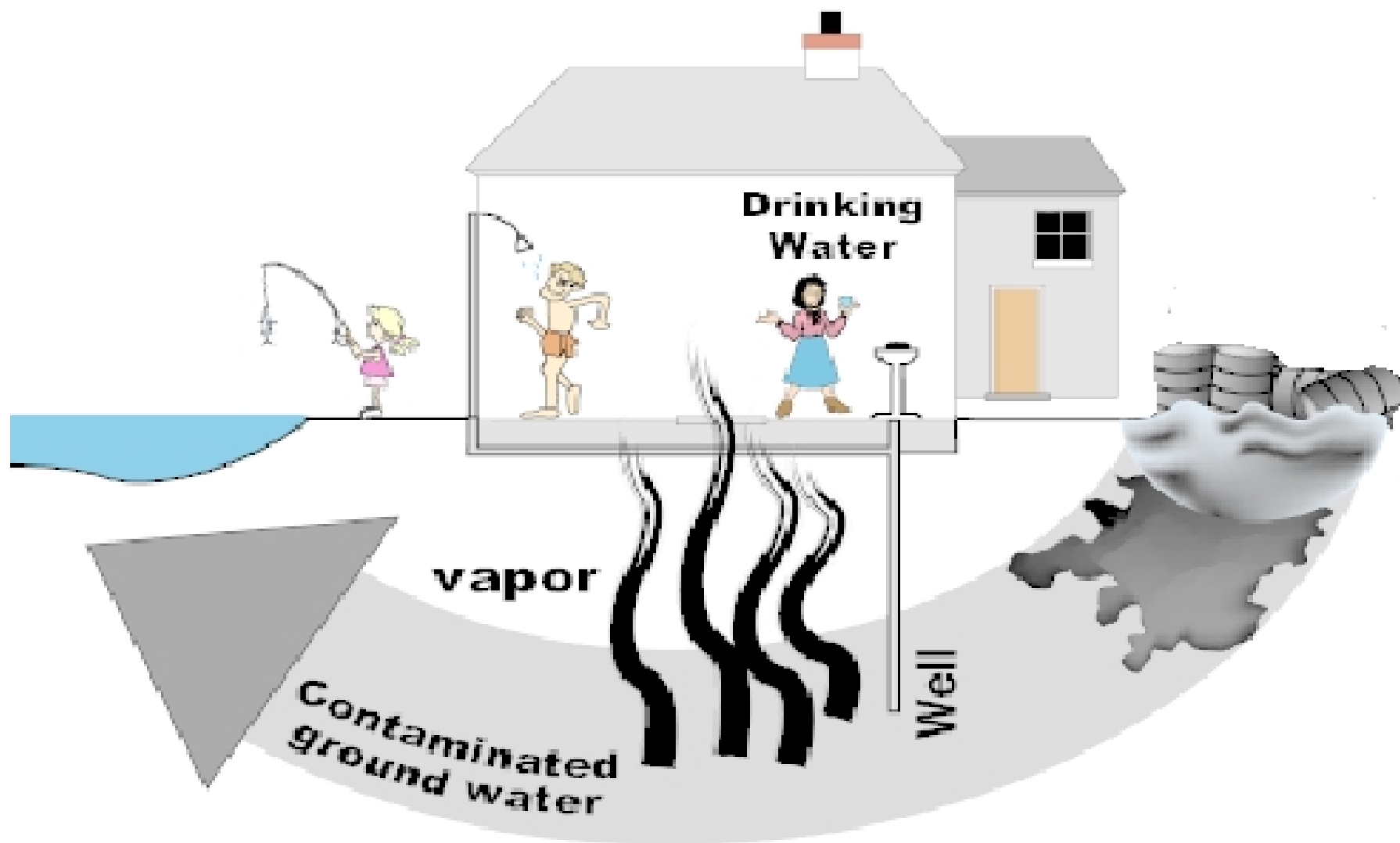
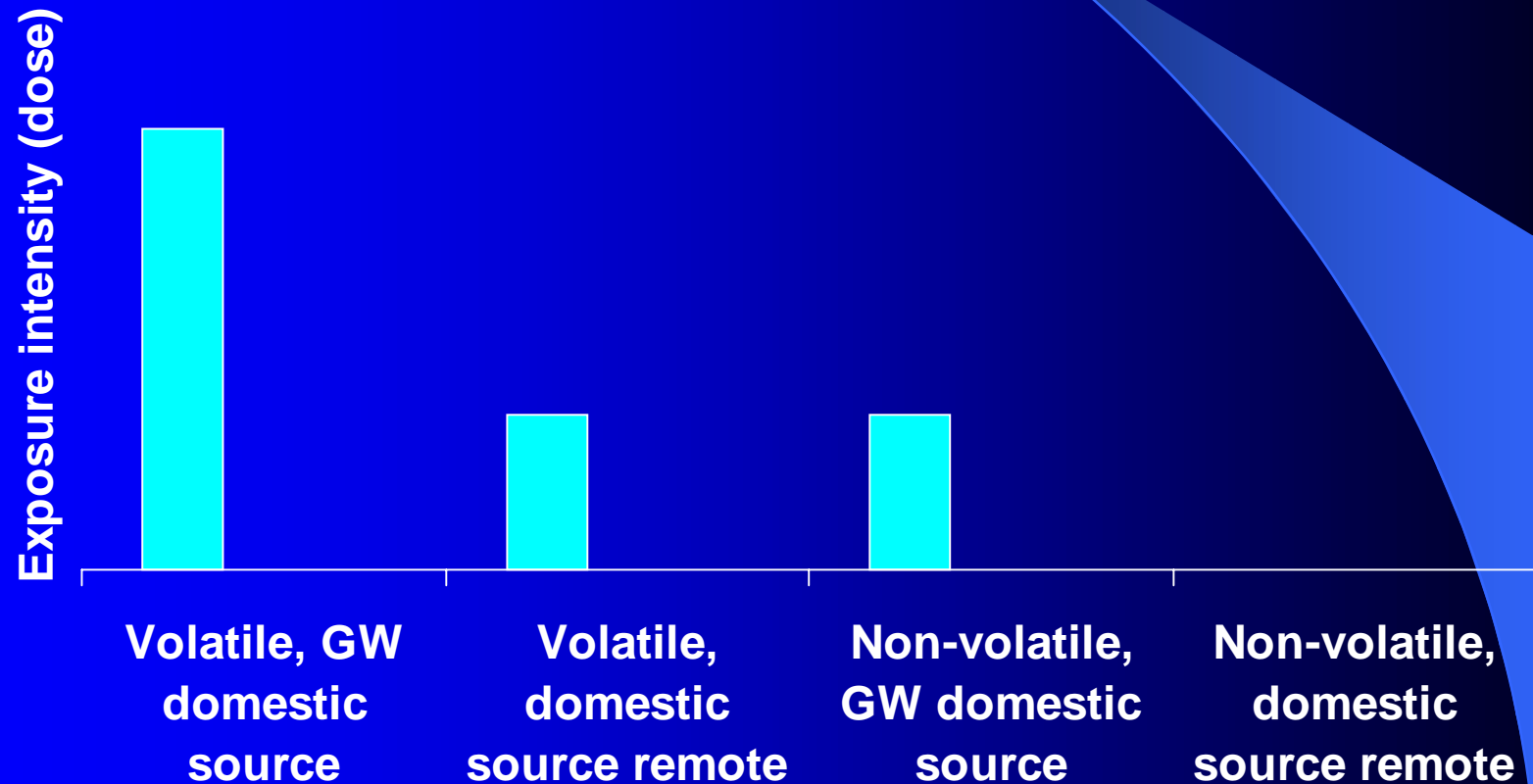


# Exposure to Groundwater

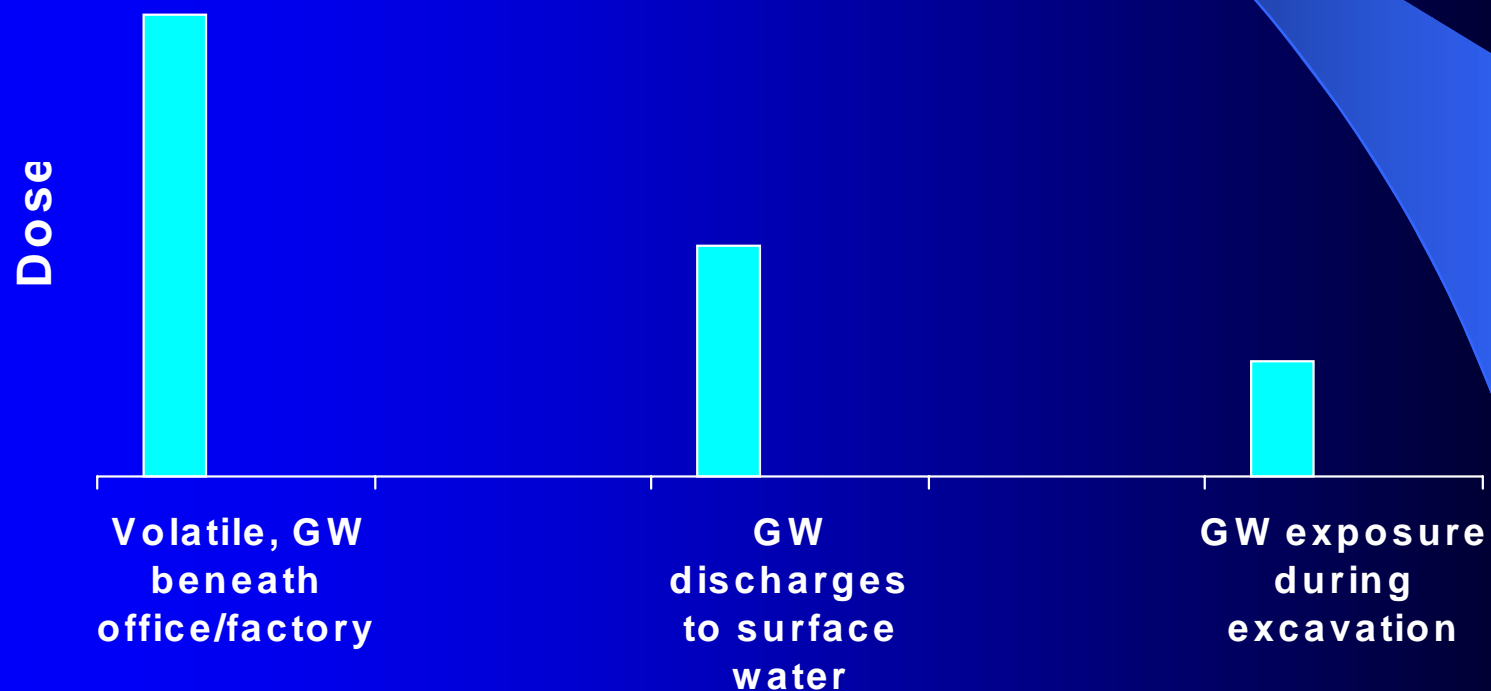
- Routes and intensity depend on....
  - “destination” (uses) of contaminated groundwater
  - AND*
  - nature of contaminants



# Exposure to Groundwater, Domestic

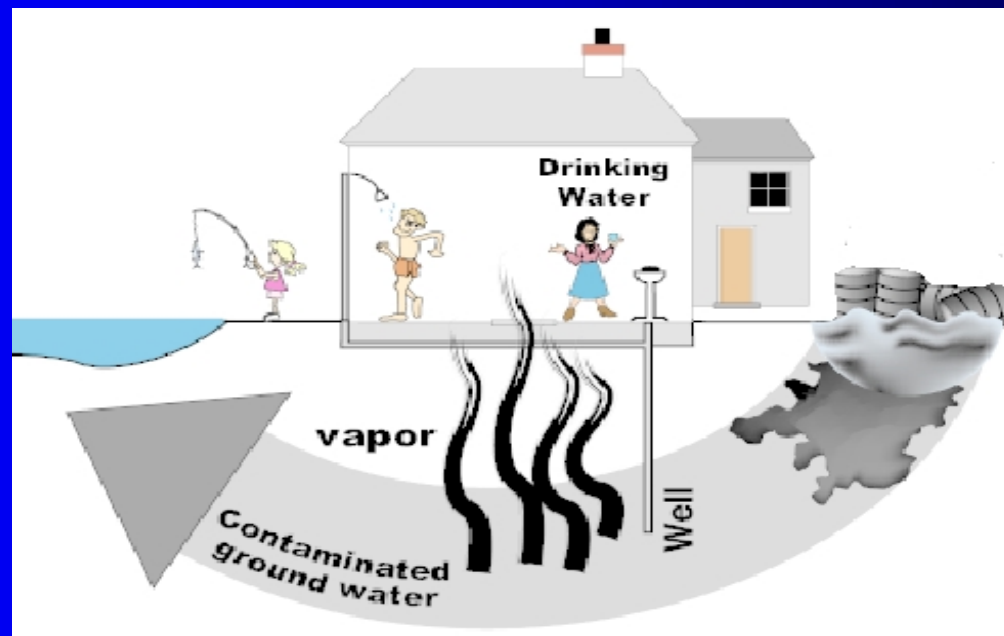


# Exposure to Groundwater, Non Domestic



# Which Exposure Routes Should be Evaluated ??

- ANS: Need a good conceptual model as well as knowledge of types of contaminants



# Commonly Evaluated Exposure Routes

- Ingestion
- Inhalation
- Dermal

# Ingestion

- In the past, typically only route evaluated
- Only exposure route considered in MCLs
- GW ingested through
  - Drinking
  - Inadvertently-swimming, showering, etc
- Straightforward evaluation

# Ingestion

Dose (measure of exposure intensity)  
depends on:

- Concentration
- Ingestion rate
- Exposure frequency
- Exposure duration
- Body weight

these factors  
are common  
to all exposure  
assessments

# Exposure Factors- Ingestion

Exposure Factor	Domestic	Domestic	Occupational
	Adult	Child	Adult
Concentration	Site-specific	Site-specific	Site-specific
IR (liters/day)	2	1	1
EF (days)	350	350	250
ED (years)	30	30	25
BW (kg)	70	15	70

# Dose Determination

- Dose typically normalized for body weight
- Lifetime average daily dose, “LADD”  
(carcinogens)
- Average daily dose, “ADD”  
(non-carcinogens)

$$\text{Dose}_{(\text{mg/kg-day})} = \frac{\text{Conc}_{(\text{mg/l})} * \text{IR}_{(\text{l/d})} * \text{EF}_{(\text{d/yr})} * \text{ED}_{(\text{yr})}}{\text{BW}_{(\text{kg})} * \text{AT}_{(\text{yr})} * 365_{(\text{d/yr})}}$$

# Inhalation

- Not included in MCLs
- Is recognized within risk assessment community as a significant exposure route for volatiles in domestic water
- Volatile: 1) Henry's Law Constant  $> 1\text{E-}5$   
2) MW  $< 200$

# Inhalation

- Contaminant in groundwater is transferred to air (tap water, vapor intrusion)
- Simple to complex models exist to approximate  
e.g. Foster and Chrostowski (1987)
- Simple model used in tap water screening tables (EPA Regions 3, 6, 9)
  - Generic “volatilization factor”

# Inhalation Dose Depends On....

- Concentration (volatilization factor, 0.5)
- Breathing rate
- Exposure frequency
- Exposure duration
- Body weight

# Exposure Factors-Inhalation

Exposure Factor	Residential	Residential	Occupational
	Adult	Child	Adult
Concentration	Site-specific	Site-specific	Site-specific
BR (m <sup>3</sup> /day)	20	12 (10)	20
EF (days)	350	350	250
ED (years)	30	30	25
BW (kg)	70	15	70

# Dose Determination

$$\text{Dose}_{(\text{mg/kg-day})} = \frac{\text{Conc}_{(\text{mg/l})} * \text{BR}_{(\text{m}^3/\text{d})} * \text{EF}_{(\text{d/yr})} * \text{ED}_{(\text{yr})} * \text{VF}}{\text{BW}_{(\text{kg})} * \text{AT}_{(\text{yr})} * 365_{(\text{d/yr})}}$$

Volatilization Factor {VF} = 0.5

# Dermal

- Recognized more recently as possibly significant
- Residential exposure primarily through bathing
- Can, for some contaminants, exceed ingestion or inhalation exposures
- Risk Assessment Guidance for Superfund (RAGS, Part E)-- draft dermal guidance

# Dermal Dose Depends On...

- Concentration
- Skin Surface Area
- Permeability Coefficient (PC)
- Event Duration ( $t_{\text{event}}$ ) and Event Frequency (EV)
- Exposure Frequency
- Exposure Duration
- Body Weight

# Exposure Factors-Dermal

Exposure Factor	Residential	Residential	Occupational
	Adult	Child	Adult
Skin Surface Area (cm <sup>2</sup> )	18,000	6,600	Site-specific
Permeability Coefficient	Chemical-specific	Chemical-specific	Chemical-specific
Event Duration (t <sub>event</sub> ) (hours)	0.58	1	Site-specific

# Exposure Factors-Dermal

- Other chemical specific factors for organic chemicals include:
  - Fraction absorbed from water
  - Lag time per event
  - Time to reach steady-state
  - Ratio of PC of a compound through “dead” skin and viable epidermis

# Dose Determination

$$\text{Absorbed Dose} = \frac{\text{DA}_{\text{event}} * \text{EV} * \text{ED} * \text{EF} * \text{SA}}{\text{BW} * \text{AT} * 365 \text{ (d/yr)}}$$

Absorbed Dose-mg/kg-day

$\text{DA}_{\text{event}}$ - mg/cm<sup>2</sup>-event

EV- events/day

ED – years

EF – days/year

SA – cm<sup>2</sup>

BW - kg

AT - yr

# Route-Specific Dose Comparison – Tapwater

Dose (mg/kg-day)

Contaminant (0.1 mg/l)	Ingestion	Inhalation	Dermal
1,2-Dichloroethane	0.0012	<b>0.0059</b>	0.00054
DDT	0.0012	NV	<b>0.14</b>
Acrylonitrile	0.0012	<b>0.0059</b>	0.00012
Carbon Tetrachloride	0.0012	<b>0.0059</b>	0.0032

# Comparisons of Risks (excess cancer risks)

Contaminant	Ingestion	Inhalation	Dermal
1,2-Dichloroethane	1.1E-4	5.4E-4	4.9E-5
DDT	4.1E-4	NV	4.8E-2
Acrylonitrile	6.5E-4	1.4E-3	6.5E-5
Carbon Tetrachloride	1.6E-4	3.1E-4	4.2E-4

# So, how do you know when to evaluate which exposure pathway?

- Highest dose does not always equate to highest risk---toxicity a factor also
- Use a risk-screening table (Region 3,6,9)—that includes ingestion and inhalation exposures
- Number of contaminants that are absorbed significantly via dermal route is low
  - EPA recommends evaluating only chemicals that contribute > 10% of oral dose

The End !